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Water Quality Index (WQI) of Selected Dug Wells in a Coastal Area in Kerala, India

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Abstract Groundwater is an important entity of our hydrological system. The present study focus on the drinking water quality status of selected dug wells of a coastal area in Kerala, India for pre monsoon and monsoon season. Of the samples collected, about 80% of the water samples are contaminated with *Escherichia coli* in pre monsoon and 100% percentage in monsoon. Iron concentrations in 65% of the water samples were found to be higher than the drinking water standards of Bureau of Indian Standards (BIS). The present study concludes that even though water comes in "good water" index, the well water is unsuitable for drinking due to its high iron and coliform contamination.

Keywords: *water quality index, Escherichia coli, ground water, water pollution*

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1. Introduction

Ground water is an essential source of water for domestic purposes to a number of settlements across the State. Groundwater is also an important environmental asset that provides base flow to streams and supports wetlands and other groundwater dependent ecosystems. In India, roughly 80% of rural water supply for domestic uses is met from groundwater [1]. The wells in villages and towns people, particularly women, from long daily walks to fetch water from springs or rivers for livestock and domestic uses. This frees time and labour for other activities. Furthermore, since water no longer has to be carried over long distances, more is often used. This can have major health benefits. In addition, because of the filtering nature of the soil and frequent long residence time underground, groundwater is commonly much cleaner than surface sources. The quantity of ground water depends on annual rainfall, percolation and storage capacity of the ground [2].

Ground water is liable to contamination through anthropogenic and other sources like use of chemical pesticides, discharge of industrial wastes, domestic and agricultural wastes. The groundwater is less contaminated than surface water [3]. It contains a wide variety of dissolved inorganic chemical constituents in different concentrations, resulting from chemical and biochemical interactions between water and the geological materials [4].

Dug wells are important groundwater extraction structures in the coastal belt of Kerala and groundwater is the most common source of drinking water in these areas. Groundwater of Kerala is getting contaminated by various effluents and anthropogenic activities [5]. Water quality of groundwater once deteriorated is irreversible, expensive to remediate and often unsuccessful. Contamination of groundwater is more complex than surface water pollution mainly because of difficulty in its timely detection and slow movement. In addition the complex geo-chemical reactions taking place in the subsurface between contaminants and earth materials are not always well-understood. Septic systems, hazardous wastes, landfills, atmospheric contamination are the major source of ground water contamination. Groundwater contamination problems are detected from many part of the state which includes a few tube wells tapping deeper confined aquifers around Alappuzha urban area have fluoride concentration in the range of 1.7 to 2.56 mg/l [6]. The major ground water quality problems of groundwater of Alappuzha is was reported to be due to chloride, TDS and fluoride [7]. So an investigation on the existing water bodies and its quality is necessary from the point of view of identifying area with high pollution and suggesting treatment measures so that water can be brought into potable levels.

2. Materials and Methods

2.1 Study Area

The study area is in Mararikulam south grama panchayat, a small coastal panchayat in Alappuzha district of Kerala, India with an area of 19.07 square kilometres. It lies between 9°36'25"N and 76°18'52"E at an elevation of 7.5 m.

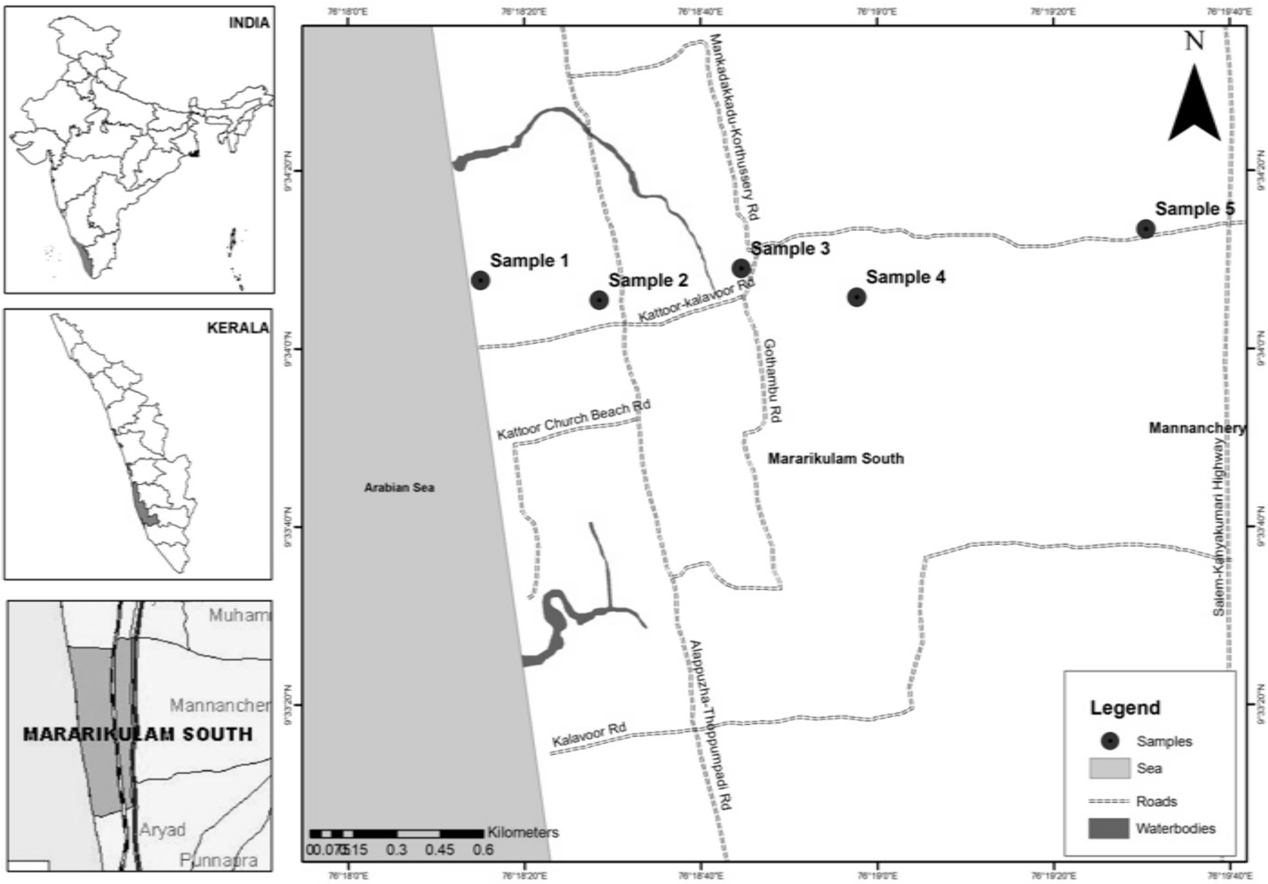

Figure 1. Map of the study area

2.2. Sample Collection and Analysis

Four samples were collected during monsoon and pre monsoon season in pre cleaned polyethylene bottles and sterilized bacteriology bottles. The sampling preservation and analysis were done as per standard methods [8]. Collected samples were analysed for various physicochemical and biological parameters, including pH, electrical conductivity (EC), total dissolved solids, total suspended solids, chloride, calcium, magnesium, total hardness, calcium hardness, fluoride, iron, TC, FC and *Escherichia coli.* The results obtained were compared with the drinking water standards as specified by Bureau of Indian Standards [9].

2.3. Statistical Analysis

The data obtained on the physicochemical and microbiological parameters of the groundwater were subjected to correlation analysis. The correlation was carried on statistical software IBM-SPSS statistics.

3. Result and Discussion

During pre monsoon season, the temperature was 30°C and during monsoon season it got reduced to a range of 25°C to 29°C. Well water showed pH in the range of 6.85 to 7.76 which is within the prescribed limit of BIS Standard [9]. Electrical conductivity of the sample analysed were with in the desirable limt of 500 µS/cm excpt for fourth sample (2370 µS/cm). High EC can be due to high dissolved ions and high alkalinity [3]. Low electrical conductivities, implying low mineral content and may therefore be referred to as fresh water [10]. Fourth sample reported high phosphate, nitrate,chloride, sulphate and is contributing to a high TDS of 1670 mg/l during pre monsoon and 1530mg/l which is above the permissible limit put forward by BIS [9]. Well water showed salinity in a range of 90.2 mg/l during monsoon to 1245 mg/l during pre monsoon. During monsoon season there is a decrease in salinity except a slight increase in 1st and 4th sample. This increase in salinity is due to the increase in chloride [11].

Total hardness was with in the range of 200 mg/l with fourth sample showing hardness value of 200 mg/l in premonsoon season. In monsoon season, there is a slight increase in the hardness value of sample1 and sample 4 having 208 mg/l and 220 mg/l respectively which is above the permissible limit of BIS (200mg/l) [9]. Lowest hardness value of 72 mg/l was found in sample 3. A high concentration of hardness may be due to leaching from the soil or due to the high background concentration of the water [12]. The higher Ca^{2+} content can cause abdominal ailments and is undesirable for domestic usage as it cause encrustation and scaling [13] In both seasons, calcium concentration in water was below the prescribed limit of 75 mg/l by BIS [9]. Magnesium values were also below the acceptable limit with concentration 7.77 mg/l and 0.97 mg/l as highest and lowest limit respectively. Chloride concentrations in water are generally up to 1000 mg/l in arid region and it imparts salty taste if concentration exceeds 100 mg/l [14]. Only well water four has a high chloride concentration above 100mg/l thus have a salty taste.

Alkalinity is the capacity to neutralize acids, Hydroxide, carbonates, and bicarbonates are the dominant source of natural alkalinity [15]. The present study shows that well water four during pre monsoon season reported high concentration (212 mg/l) which is slightly above the acceptable limit of 200 mg/l [9] and all other samples reported concentration within acceptable limit. Aeration of iron-containing layers in the soil can affect the quality of both groundwater and surface water if the groundwater table is lowered or nitrate leaching takes place. Dissolution of iron can occur as a result of oxidation and decrease in pH [9]. In the study area during pre monsoon season 60 % of the sample reported values more than the acceptable limit put forward by BIS [9]. But in rainy season, it got reduced to 20%. The values ranged from 0.08 mg/l to 0.41 mg/l. High concentration of iron in groundwater may not pose any health hazards but may not be patronized by consumers due to unpleasant odour and taste that is normally associated with groundwater with higher iron concentrations. In potable water, iron is objectionable because, it gives bitter taste and excessive concentration of iron cause gastrointestinal upset and moreover it stains the cloth, teeth, gums and utensils [16].

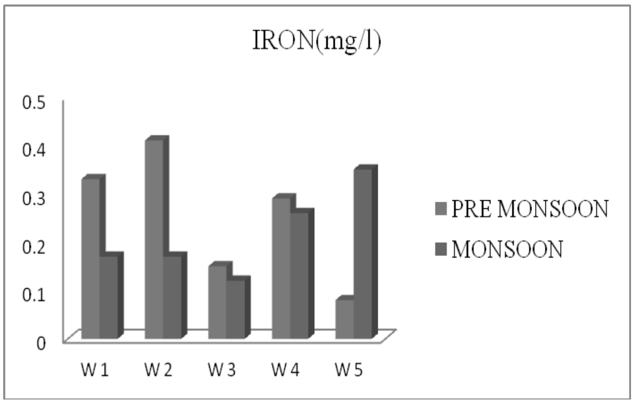

Figure 2. Variation of iron in different seasons

Fluoride level ranged from 0.09mg/l to 0.32mg/l during pre monsoon season and 0.2mg/l to 0.47mg/l during monsoon which is well below the BIS [9] standard of fluoride. The presence of phosphate and nitrate in water is becoming a worldwide problem because of deterioration of the quality of water [17]. Water analysis has shown a minimum level of nitrate which is in the range of 0.95 mg/l to 5.58 mg/l and was within the acceptable limit. Sulphate occurs naturally in water. Many minerals present in soil gets dissolved into water and ultimately released as sulphate in water. High level of sulphate in water can cause diarrhoeal problems [18].

The presence of *Escherichia coli* in water sample usually indicates recent faecal contamination [19]. The result showed that 80% of the sample was contaminated by *Escherichia coli* during pre monsoon season. During monsoon all samples got contaminated with *Escherichia coli*, which may be due to the reduced action of interception, straining, adsorption, and sedimentation in soil due to the faster movement of *Escherichia coli* through soil, by flushing action of rain water [20]. Heavy metal analysis of ground water samples during pre monsoon season shows that well water only have the presence of cadmium and lead in well water that is well below the acceptable limit of BIS [9]. The heavy metal concentration was high in premonsoon season [21,22].

3.1. Correlation Matrix

Statistical analysis was performed on the physico-chemical parameters and major ion concentration to detect the relationship and differences between the groundwater samples. Correlation analysis of groundwater samples during pre-monsoon season showed that, TDS is significantly correlated with anions like chloride (r=0.996) and sulphate (r=0.960). It also showed significant correlation with magnesium(r=0.982) which forms soluble precipitate in water source. Pairs of anions are positively correlated like sulphate –chloride (r=0.979), hardness-chloride (r=0.574), hardness-sulphate (r=0.406). The above result shows an excellent correlation between sulphate and chloride. Hardness have a strong significant correlation with alkalinity (r=0.984). Hardness of water sample is significantly correlated with anions namely chloride, sulphate and cations, calcium and magnesium. Hence from correlation analysis it is clear that hardness is of both types temporary and permanent.

Correlation analysis during monsoon showed a significant correlation between EC and chloride (r=0.992), sulphate (r=0.916), and salinity (r=1). Hardness has significant positive correlation with calcium (r=0.797), magnesium (r=0.325), chloride (r=0.634), sulphate (r=0.446) and alkalinity (r=0.998). This shows that hardness is of both temporary and permanent. TDS is significantly correlated with nitrate (r=0.926) which forms the soluble precipitate of surface water. Calcium and magnesium shows significant positive correlation (r=0.714). This type of positive significant correlation of metal ions indicates that metal ions are from same source (Table 1 - Table 2).

Table 1. Correlation matrix of well water parameters in pre monsoon season

	pH	EC	TDS	TA	TH	Ca	Mg	Cl^-	SO_4	Salinity	NO_3	PO_4
pH	1											
EC	-0.313	1										
TDS	-0.31	1	1									
TA	0.256	0.753	0.755	1								
TH	0.335	0.638	0.64	0.984	1							
Ca	0.863	-0.302	-.298	0.396	0.524	1						
Mg	-0.374	0.982	0.982	0.765	0.671	-0.279	1					
Cl^-	-0.367	0.997	0.996	0.698	0.574	-0.375	0.974	1				
SO_4	-0.638	0.961	0.96	0.543	0.406	-0.552	0.938	0.979	1			
Salinity	-0.323	1	1	0.745	0.629	-0.313	0.981	0.998	0.964	1		
NO_3	-0.295	0.914	0.913	0.519	0.364	-0.485	0.833	0.934	0.943	0.971	1	
PO_4	-0.327	0.906	0.906	0.753	0.691	-0.205	0.958	0.889	0.856	0.903	0.72	1

Table 2. Correlation matrix of well water parameters in monsoon season

	pH	EC	TDS	TA	TH	Ca	Mg	Cl^-	SO_4	Salinity	NO_3	PO_4
pH	1											
EC	0.168	1										
TDS	0.17	1	1									
TA	0.867	0.626	0.628	1								
TH	0.791	0.728	0.729	0.988	1							
Ca	0.984	0.167	0.169	0.871	0.797	1						
Mg	0.692	-0.306	-0.305	0.387	0.325	0.714	1					
Cl^-	0.043	0.992	0.991	0.522	0.634	0.039	-0.385	1				
SO_4	-0.137	0.916	0.916	0.341	0.446	-0.157	-0.596	0.951	1			
Salinity	0.162	1	1	0.622	0.723	0.161	-0.312	0.993	0.92	1		
NO_3	-0.212	0.926	0.926	0.288	0.421	-0.211	-0.486	0.966	0.95	0.928	1	
PO_4	0.682	0.36	0.362	0.684	0.706	0.661	0.829	0.274	-0.011	0.354	0.13	1

3.2. Water Quality Index

For computing water quality index, three steps are followed. In the first step, each of the nine parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment [15]. Magnesium which is given weight of 2 as magnesium by itself may not be that harmful [12] Second step, relative weight (W_i) is computed from the following equation:

$$W_i = w_i / \sum^{n}_{i=1} w_i$$

Where (Wi) is the relative weight, (w_i) is the weight of each parameter and ‘n’ is the number of parameters. The Calculated Water Quality Index of drinking water in Patna is also given in the Table I. In the third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result is multiplied by 100

$$q_i = \left(C_i / S_i\right) * 100$$

Where $\mathbf{q_i}$ is the quality rating, $\mathbf{C_i}$ is the concentration of each chemical parameter in each water sample in mg/l, and **Si** is the BIS (Bureau of Indian standards) water standard for each chemical parameter in mg/l according to the guidelines of the BIS and WHO. For computing the WQI, the SIi is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation

$$SIi = Wi * qi$$

$$WQI = \sum SIi$$

SIi is the sub index of Ith parameter, qi is the rating based on concentration of ith parameter and **n** is the number of parameter. The computed WQI values are classified into five types “excellent water”, “good water”, “poor water” “very poor water” and “water unsuitable for drinking” as shown in the Table 4.

Water Quality Index (WQI) is one of the most effective tools to provide feedback on the quality of water to the policy makers and environmentalists. It provides a single number expressing overall water quality status at a particular and location [24,25]. The WQI of well water in the study area is 61.89 which can be categorised as “good water” category as per the water quality classification based on WQI value. But the presence of faecal and total coliforms in water make them unfit for drinking (Table 3). The single parameter, “coliform bacteria” which has high significance in determining the quality of drinking water has to be thoroughly studied and to be checked.

Table 3. Water quality index of dugwells

	Concentration of parameters (mg/l) (Ci)	Weightage (wi)	Relative weight (Wi)	Standard Concentration (mg/l) (Si)	Quality Rating (qi)	Sub Index (SIi)
TDS	529	5	0.26	500	105.8	27.50
Chloride	156.9	3	0.10	250	62.67	6.26
Total hardness	148	3	0.10	300	49.33	4.93
Calcium	46.72	2	0.07	75	62.29	4.36
Magnesium	2.71	2	0.07	30	9.03	0.63
Nitrate	8.11	5	0.26	45	18.02	4.68
Sulphate	52.68	4	0.13	200	26.34	3.42
Fluoride	0.292	4	0.13	1	29.2	3.79
Alkalinity	126.4	3	0.10	200	63.2	6.32
WQI=61.89						

Table 4. Water quality classification based on water quality index [23]

WQI Value	Water Quality
<50	Excellent
50 – 100	Good water
100 – 200	Poor water
200 – 300	Very poor water
>300	Water unsuitable for drinking

4. Conclusion

Groundwater is the major source of drinking water in coastal belt of Alappuzha district of Kerala. Quality of groundwater with immense importance in the life of people is getting deteriorated in many places. In the present study groundwater showed high concentration of iron and coliform bacteria. There must be a participatory approach in water conservation to address these problems as well as to check the water quality in the area. The present study concludes that even though water comes in "good water" index, but is unsuitable for drinking due to its high iron and coliform contamination. Preventive management is the preferred approach to drinking-water safety and should take account of the characteristics of the drinking-water from source to its consumers.

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